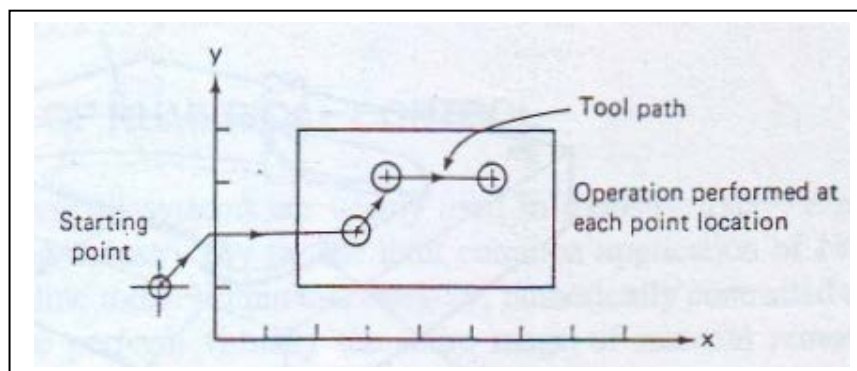# *Positioning Control System*

In order to accomplish the machining process, the cutting tool and workpiece must be moved relative to each other. In NC, there are three basic types of motion control system (Point-to-point, Straight cut and Contouring).

Point-to-point systems represent the lowest level of motion control between the tool and workpiece. Contouring represents the highest level of control.

## *1-Point-to-point Positioning Control:* -

Point-to-point (PTP) is also sometimes called a positioning system. In PTP, the objective of the machine tool control system is to move the cutting tool to a predefined location. The principle function of the PTP is to position the tool form one point to another within coordinate system. The positioning may be linear in the x-y plane or linear and rotary if the machine has a rotary table. Each tool axis is controlled independently, therefore; the programmed motion always in rapid travers. Once the tool reaches the desired location, the machining operation is performed at that position (machining can only take place after positioning is completed).

NC drill presses are a good example of PTP systems. The spindle must first be positioned at a particular location on the workpiece. This is done under PTP control. Then the drilling of the hole is performed at the location, and so forth. Since no cutting is performed between holes, there is no need for controlling the relative motion of the tool and workpiece between hole locations. Figure (1) illustrates the point-to-point type of control.

Fig(1): Point-to-point (positioning) NC system

Positioning systems are the simplest machine tool control systems and are therefore the least expensive of the three types. However, for certain processes, such as drilling operations, tapping, riveting and spot welding, PTP is perfectly suited to the task and any higher level of control would be unnecessary. Example bellow illustrate path of three drilled holes.
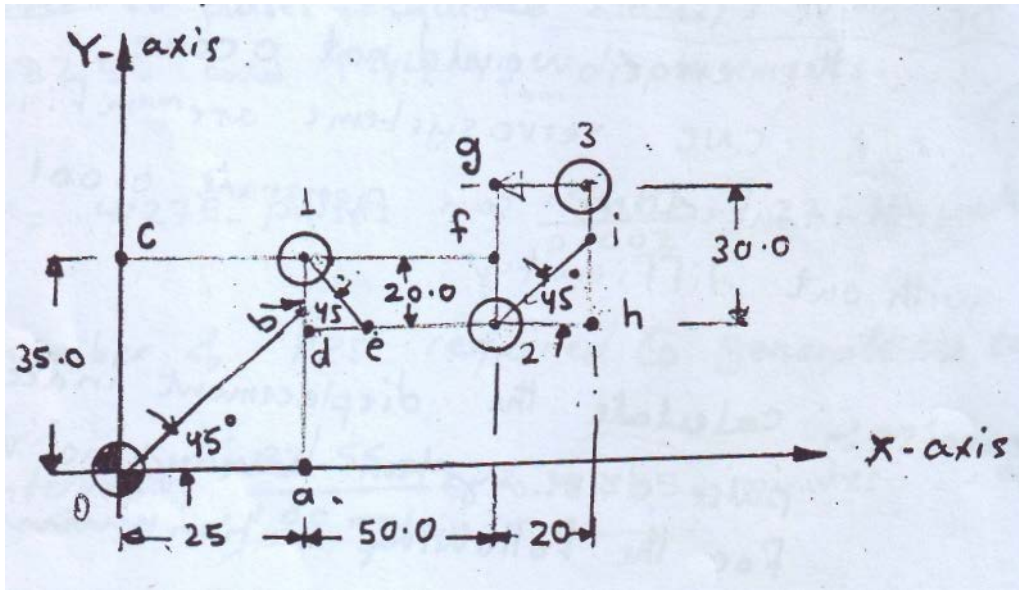
Path of three drilled holes				
Programmed	Tool path		Motion	
	Sequential	Simultaneous	from	to
x25.0 y35.0	0-a-1	0-b-1	0	1
x50.0 y-20.0	1-d-2	1-e-2	1	2
x20.0 y30.0	2-h-3	2-i-3	2	3

Sequential: - the system will move in one axis at a time.

Simultaneous: - both axes start at the same time, the tool path will be approximately.

2-Straight-cut Positioning Control: -

Straight-cut control systems are capable of moving the cutting tool parallel to one of the major axes at a controlled rate suitable for machining. It is therefore appropriate for performing milling operations to fabricate workpieces of rectangular configurations. Most of the straight-cut systems an fitted with manually adjustable feed control, this feed control is shared by all the programmable axes of the NC machine, because of this shared feed control feature; the system can also perform milling operation at 45° to the primary axes of the machine. An example of a straight cut

operation is shown in Figure (2). An NC machine capable of straight cut movements is also capable of PTP movements.
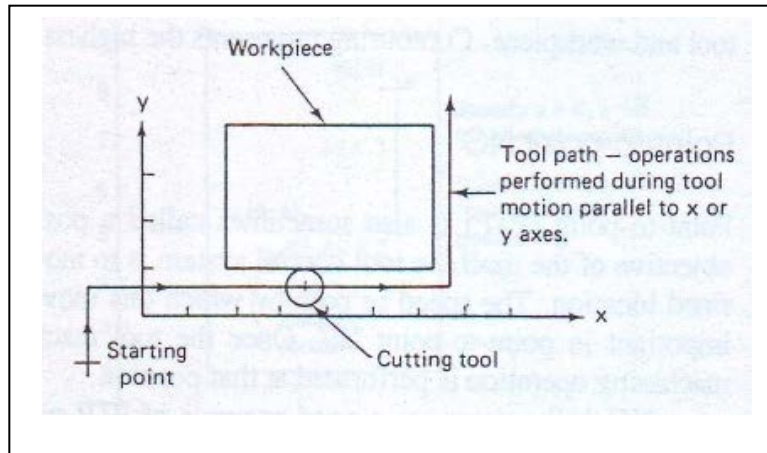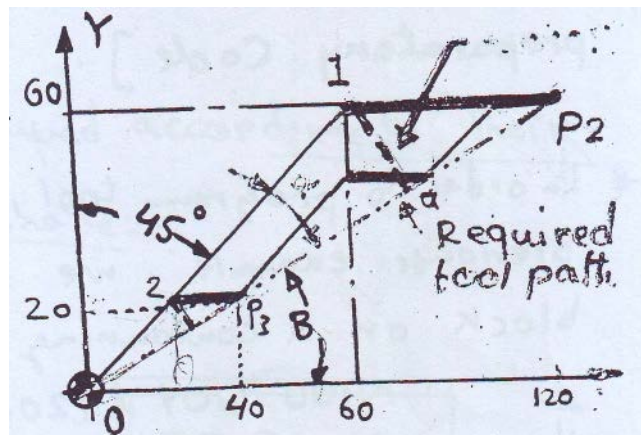

Fig (2): Straight-cut system

Example: - the coordinate of P_2 are x120mm and y60.0mm programming these dimension would result in a tool path from 0 to 1 to P2 with the following error:

Error: distance $1a = 01 \sin\alpha$

$$\sqrt{x_1^2 + y_1^2} * \sin\alpha = \sqrt{2y_1^2} * \sin\alpha$$

$\alpha = 45° - \beta; \quad \beta = 26.565° \quad \rightarrow xy coordinates; \ \alpha = 18.435°$

$Error = \sqrt{2y^2} * \sin 18.435 = \sqrt{2 * 60^2} * \sin 18.435 = 26.8328 \ mm$ ----------------too large

Reducing the programmed increments to x40.0mm y20.0mm, will result the tool path of 0 to 2 to p3.

$$Error = \sqrt{2y^2} * sin18.435 = \sqrt{2*20^2} * \sin 18.435 = 8.944 \ mm$$

This value 8.944 is proportionally less, but still for too large. Reducing the programmed increments to x0.5 y0.25.

$Error = \sqrt{2y^2} * sin18.435 = \sqrt{2*0.25^2} * \sin 18.435 = 0.039 \ mm$. This value is efficient.

      In order to program tool path from point 0 to p1 in the previous example, we would require a single tape block on a contouring system:

N100 G01 x120.0 y60.00 F…..

      Using the straight cut system, the program shown bellow will require 240 tape blocks and will only yield a tolerance of 0.039mm.

N1…….. x0.50 y0.25   from point (0, 0) to point (x0.5, y0.25)

N2…….. x0.50 y0.25   to point (x1, y0.5)

N1…….. x0.50 y0.25   to point (x1.5, y0.75)

-

-

-

N1…….. x0.50 y0.25   to (x120, y60)

Example: - calculate the increments to be programmed to produce the tool path with less than 0.03mm error from P_1 (11.32, 9.82) to P_2 (113.82, 64.32)?

3-Contouring (continuous) Path CNC System: -

Contouring is the most complex, the most flexible, and the most expensive type of machine tool control. It is capable of performing both PTP and straight-cut operations. In addition, the distinguishing feature of contouring NC systems is their capacity for simultaneous control of more than one axis movement of the machine tool. The path of the cutter is continuously controlled to generate the desired geometry of the workpiece. Contouring system generates a continuously controlled tool path by the capability of computing the points of the path (interpolating). For this reason, contouring systems are also called continuous-path NC systems. All NC contouring system have the ability to perform linear and circular or parabolic interpolation features which recorded in the NC computer under a (G preparatory code). Figure (3) illustrates the versatility of continuous path NC. Milling and turning operations are common examples of the use of contouring control.
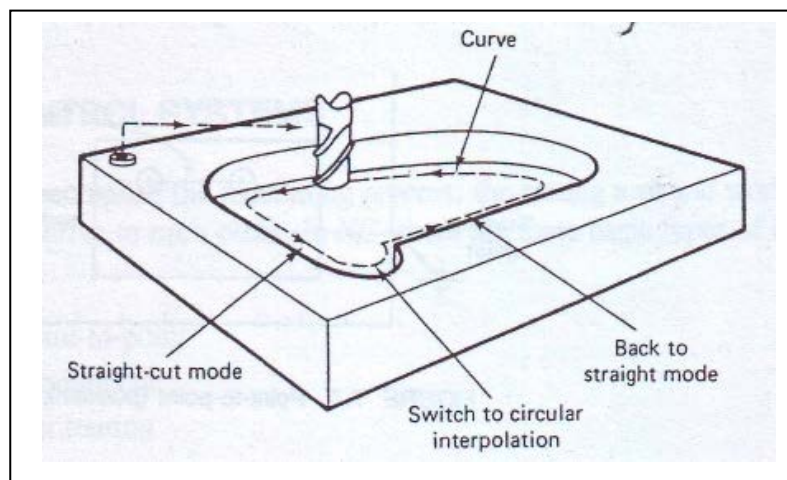

Fig (3): contouring (continuous path) NC system for two dimensional operations

Accuracy and repeatability

Two of the important features of a numerical control system are its accuracy and repeatability. The accuracy of an NC system is related to its control resolution. The term control resolution refers to the MCU's capability to divide the range of a given axis movement into closely spaced points that can be identified by the controller.

If n represents the number of bits for an axis, the number of control points is given by

$$\text{number of control points} = 2n$$

The control resolution is therefore defined as the distance between adjacent control points, and can be determined by

$$CR = \text{range of axis movement}/2^n$$

Accuracy is a measure of the control system's capacity to position the machine table at a desired location, which is defined by a set of axis coordinate values.

$$\text{Accuracy} = (CR/2) + 3 \text{ (std. dev. of mech. error)}$$

The definition of accuracy is pictured in Fig (12).

Repeatability is defined in terms of the ability of the control system to return to a given location that was previously programmed into the controller. Repeatability affects the capacity of the NC machine tool to produce parts that do not vary in machined dimensions from one part to the next. repeatability can define:

$$\text{Repeatability} = \pm 3 \text{ (std. dev. of mech. error)}$$

$$= 6 \text{ (std. dev. of mech. error)}$$

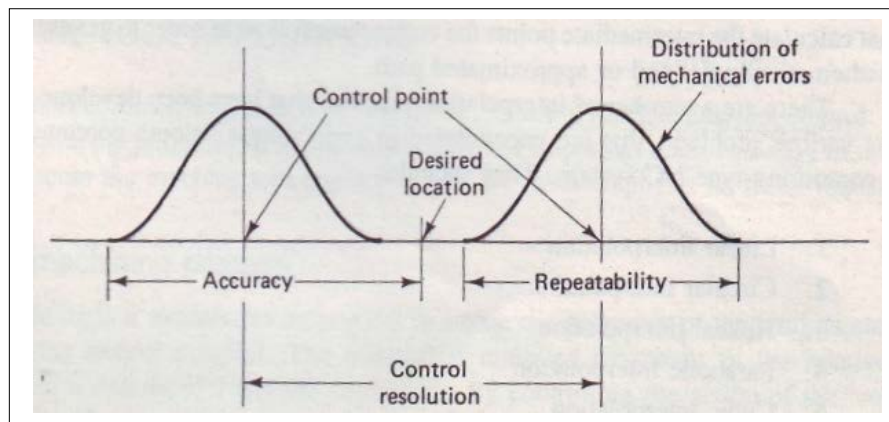Our definition of repeatability is illustrated in Fig (12).

Fig (12) Accuracy and repeatability for linear axis

Example:

A two-axis NC control system used as an x-y positioning table has a bit storage capacity of 12 bits for each axis. Both x and y axes have a range of 15 in. The mechanical accuracy of the machine table can be characterized by a normal distribution

with standard deviation = 0.0003 in. for both axes. Determine (a) the control resolution, (b) the accuracy, and (c) the repeatability of the NC system.

Solution:

(a) The control resolution is determined by

      CR = 15.0 in/2¹² = 15/4096 = 0.00366 in.

(b) The accuracy is defined as

      Accuracy = 0.00366/2+ 3(0.0003) = 0.00273 in.

(c) The repeatability, by our definition, is

      Repeatability = 6(0.0003) = 0.0018 in.

Economic of NC

There are a number of reasons why NC systems are being adopted so widely by the metalworking industry. It has been estimated that 75% of manufacturing is carried out in lost sizes of 50 or less. As indicated above, these small lot sizes are the typical applications for NC. Following are the advantages of numerical control when it is utilized in these small production quantities:

1-Reduced nonproduction time: - It accomplishes this decrease in nonproductive time by means of fewer setups, less setup time, reduced workpiece handling time, automatic tool changes on some machines, and so on.

2- Reduced fixturing: - NC requires simpler fixtures because the positioning is done by the NC program rather than the fixture or jig.

3- Reduced lead time: - Jobs can be set up more quickly with NC.

4- Greater manufacturing flexibility: - NC adapts better to changes in jobs, pro-duction schedules, and so on.

5- Easier to accommodate engineering design changes on the workpiece: -

6- Improved accuracy and reduced human error; - NC is ideal for complicated parts where the chances of human mistakes are high.

Where is NC most appropriate?

It is clear from the advantages listed above that NC is appropriate only for certain parts, not all parts. The general characteristics of jobs for which NC is most appropriate are the following:

1-Parts are processed frequently and in small to medium lot sizes.

2- Part geometry is complex.

3- Close tolerances must be held on the workpart.

4- Many operations must be performed on the part in its processing.

5- Much metal needs to be removed (for machining applications).

6- Engineering design changes are likely.

7- It is an expensive part where mistakes in processing would be costly.

8- Parts require 100% inspection.